A study on photosynthetic characteristics of *Betula platyphylla*

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Abstract: Influences of temperature, humidity, and CO_2 concentration on the photosynthesis and respiration of three-year-old *Betula platyphylla* was investigated. Light compensation point, saturation point and CO_2 compensation point were also determined. The results showed that the optimal temperature of photosynthesis and dark respiration was 24℃ and 30℃, respectively, at ambient CO_2. When relative humidity was 80%, *Betula platyphylla* could maintain strong photosynthesis. There was no significant correlation between respiration and relative humidity. The light compensation and saturation point was 25 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and 1 375 $\mu mol \cdot m^{-2} \cdot s^{-1}$, respectively. The CO_2 compensation point was 180 $\mu L \cdot L^{-1}$. The results showed that *Betula platyphylla* still had potential to assimilate CO_2 when CO_2 concentration was above 2 400 $\mu L \cdot L^{-1}$.

Keywords: *Betula platyphylla*; Photosynthesis; Respiration; CO_2 concentration

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Introduction

Birch *(Betula platyphylla)* is an important tree species in northeast of China and has a higher growth potential and better stem quality, compared to other species. Birch has many advantages as breeding material, based on its biological characteristics (Lepistö 1972, 1973). Photosynthesis is the basis of other physiological activities including growth, development, and food formation in trees. Many researches on phytogengraphy (Chen 1994), behaviors of nitrogen nutrition (Cui 1998), cutting propagation (Zhan *et al.* 1994) in birch were conducted. But there are few studies on the photosynthetic characteristics of *Betula platyphylla.* Photosynthesis is related to temperature, light radiation and CO_2 concentration, which are necessary to value photosynthetic capacity. This study reports influences of temperature, humidity, and CO_2 concentration on the photosynthesis and respiration of three-year-old *Betula platyphylla*.

Materials and methods

Mature upper leaf was selected for measuring of net photosynthetic rate by a portable infra-red gas analyzer with an open-flow mode (Qiu 1985). At the given concentration of CO_2, light compensation point and light saturation point were determined under different light radiation gained by covering white and black cloth on the leaf chamber. During measuring, we used compounded CO_2 in advance to prevent the fluctuation of CO_2 and ensure the stable concentration of CO_2. The CO_2 exchange of measured leaf is dark respiration when light radiation is zero.

Results

Response of net photosynthetic rate and dark respiratory rate to temperature

The net photosynthetic rate and dark respiratory rate were measured at different temperature under the stable light photo flux density of 540 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and relative humidity of 80%. Fig.1 showed the optimal temperature is 24℃ for photosynthesis and 30℃ for dark respiration at the specific condition.

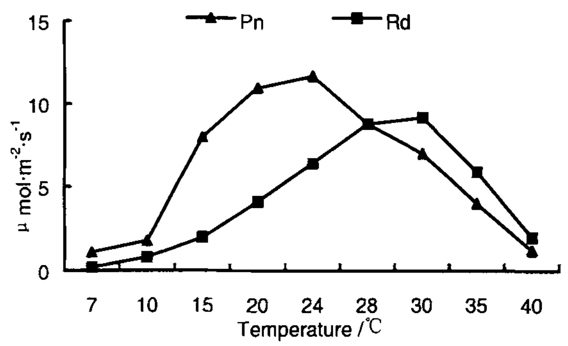

Fig.1 The response of net photosynthetic rate (Pn) and the absolute value of dark respiratory rate (Rd) to temperature

Within the scope of relatively low temperature, dark respiratory rate increased slowly with the increase of tem-

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perature, while net photosynthetic rate appeared opposite trend. After reaching the maximum value, the photosynthesis rate and dark respiration rate, two both curves decreased sharply though the temperature increased. At 7℃, photosynthesis and dark respiration were weak, but the former was slightly higher than the latter. Between 10℃ and 24℃, the increase of photosynthesis was obviously faster than that of respiration. At the crossover of two curves (28℃), the net photosynthetic rate was equal to dark respiratory rate. After 28℃, the decline of photosynthesis decreased markedly compared with that of dark respiration.

Response of net photosynthetic rate and dark respiratory rate to relative humidity

The net photosynthetic rate and dark respiratory rate were measured at different relative humidity: 50%, 60%, 70%, 80%, and 90% at the temperature of 25℃ and light photo flux density 540 $\mu mol \cdot m^{-2} \cdot s^{-1}$. From Fig.2, we found the curve of photosynthesis to relative humidity was 's' shape while that of dark respiration was relatively gentle. The photosynthesis was affected more significantly by humidity at specific condition. Relative humidity did not have remarkable effect on respiration of *Betula platyphylla*. Dark respiratory rate had small increase with the change of relative humidity. The net photosynthetic rate increased rapidly when relative humidity was less than 80% but increased little when relative humidity was above 80%.

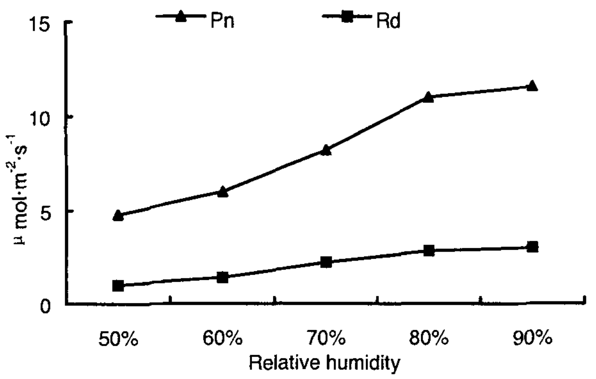

Fig.2 The response of net photosynthetic rate (Pn) and the absolute value of dark respiratory rate(Rd) to relative humidity

Response of net photosynthetic rate to light radiation

On sunny day, the net photosynthetic rate was measured under different light radiation. Fig.3 indicated that the net photosynthetic rate increased with the increase of light radiation and reached saturation under about 1 375 $\mu mol \cdot m^{-2} \cdot s^{-1}$ light radiation. The value of photosynthetic rate was zero when light radiation was about 25 $\mu mol \cdot m^{-2} \cdot s^{-1}$. At the condition of 18℃ and 390 $\mu L \cdot L^{-1}$ CO_2, the light compensation point was 25 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and light saturation point was 1 375 $\mu mol \cdot m^{-2} \cdot s^{-1}$ for three-year-old *Betula platyphylla*. The net photosynthetic rate increased linearly within the scope of 0 to 250 $\mu mol \cdot m^{-2} \cdot s^{-1}$ light radiations. Within the range of intense light radiation between 625 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and 1 375 $\mu mol \cdot m^{-2} \cdot s^{-1}$, the increase of net photosynthetic rate was relatively slow. The net photosynthetic rate rarely changed at above 1 375 $\mu mol \cdot m^{-2} \cdot s^{-1}$ light radiation.

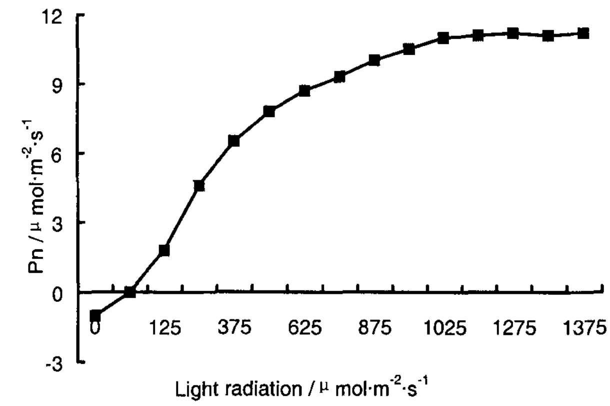

Fig.3 The response of net photosynthetic rate (Pn) to light radiation

Response of net photosynthetic rate to CO_2 concentration

Fig.4 showed that the net photosynthetic rate increased with the increase of CO_2 concentration. The net photosynthetic rate increased slowly when CO_2 concentration exceeded 1 200 $\mu L \cdot L^{-1}$. The *Betula platyphylla* still had potential to uptake CO_2 under 2 400 $\mu L \cdot L^{-1}$ CO_2. There was a point of inflection, about 1 200 $\mu L \cdot L^{-1}$ CO_2, which restricted the assimilation rate. The photosynthetic rate of *Betula platyphylla* increased linearly within the scope of 400-1 200 $\mu L \cdot L^{-1}$ CO_2.

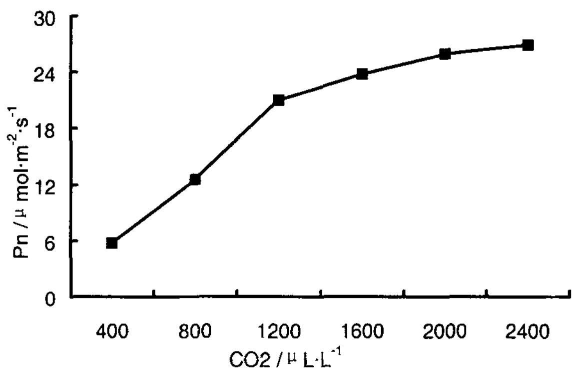

Fig.4 The response of net photosynthetic rate (Pn) to CO_2 concentration

Measurement of CO_2 compensation point

The CO_2 compensation point of three-year-old *Betula platyphylla* was determined with close flow system under stable condition that temperature was 24℃, relative humidity was 80%, and light radiation was 540 $\mu mol \cdot m^{-2} \cdot s^{-1}$. After reaction of 40 min, the leaves balanced the uptake and release of CO_2, and the CO_2 concentration in the leaf chamber did not change. Then the CO_2 compensation point

was 180 $\mu L \cdot L^{-1}$. Plants maintain photosynthesis only when the CO_2 concentration is above the CO_2 compensation point. The CO_2 concentration released by respiration could exceed that assimilated by photosynthesis when ambient CO_2 concentration is under about 180 $\mu L \cdot L^{-1}$ for *Betula platyphylla*. The plants appear respiration and consume accumulated organic matter.

Discussion

The values of CO_2 compensation point, light compensation point and saturation point are not changeless and are environmental dependence. The physiological indexes related to photosynthesis above were meaningful to plant growth and production.

The rapid decline of net photosynthetic rate and dark respiratory rate at the range of high temperature was associated to the decrease of some enzyme activity. Especially RuBPcase is the initial CO_2-fixing enzyme in C_3 species and it may limit net CO_2 uptake (Nobel 1991; Dressman *et al.* 1994; Nadu and Wang 1995). *Betula platyphylla* is cold-resistant species and can maintain photosynthesis at lower temperature. At 7℃, *Betula platyphylla* still assimilates CO_2 and accumulates organic matter. When environmental temperature is above 28℃, *Betula platyphylla* begins to respirate and decompose organic matter which is disadvantageous to the growth. The transpiration of leaves is accelerated when atmospheric relative humidity is low, and stomata closed to avoid losing much water. As the substrate of photosynthesis, CO_2 diffuses into cell through stomata. The closure of stomata restrained the diffusion of CO_2 into photosynthetic tissue, thus resulted in the decline of photosynthesis.

Light is the power in photosynthesis. Light compensation point is a critical value, over this value plant still can maintain photosynthesis. Light saturation point is a limit value, over this value photosynthetic rate does not increase, even decrease. *Betula platyphylla* is a shade-avoiding species, and it can produce strong photosynthetic rate when the light radiation exceeds 625 $\mu mol \cdot m^{-2} \cdot s^{-1}$. The indexes relating to light radiation in this experiment were measured at the specific condition that temperature, pressure, and CO_2 were constant. These factors will change if environment condition changes. Light compensation point and light saturation point alter with the increase or decrease of temperature and/or CO_2 concentrations.

The concentration of atmospheric CO_2 cannot decrease to the CO_2 compensation point, but in the dense canopy and low-level leaves the CO_2 concentration may be lower than CO_2 compensation point. In practice, reasonable and scientific density of vegetation can ensure enough light and CO_2 to produce photosynthesis.

It is strong evidence that plants have already responded to the increase in atmospheric CO_2 concentration that has occurred since the onset of the Industrial Revolution (Woodward 1987; Overdieck *et al.* 1988; Dippery *et al.* 1995). Atmospheric CO_2 concentrations are projected to be double from the current concentration of 350 $\mu L \cdot L^{-1}$ to 700 $\mu L \cdot L^{-1}$ within the next 80 years, which will further stimulate plant and ecosystem (Ward 1999). CO_2 concentration is the main restriction factor of photosynthesis for C_3 species when temperature is moderate and light radiation is saturated. Most studies showed that photosynthetic rate was increased following initial exposure to elevated CO_2 (Ward 1999). Increased availability of CO_2 at the chloroplasts brought about the increases in photosynthetic rate and reductions in photorespiration resulting from an increased ratio of CO_2 to O_2 (Farquhar 1982; Pearcy *et al.* 1987). However, many studies reported that high photosynthetic rates can not maintain over long time periods and substantial reductions in photosynthesis (down-regulation) may occur within days to weeks after initial exposure to elevated CO_2 (Delucia *et al.* 1985; Gunderson and Wullschleger 1994; Long *et al.* 1993; Sims *et al.* 1998). Exposure to high CO_2 concentration, the photosynthetic rate may increase, decrease or unchanged compared with that of plants grown at ambient CO_2, which was related to treatment of long-term or short-term. In our experiment, *Betula platyphylla* only experienced short-term and discontinuous treatment of high concentration of CO_2 every day, thus the plants have enough time to have the cell resume and allocate photosynthate. *Betula platyphylla* showed strong photosynthetic potential at high CO_2 concentrations, which indicated that the treatment of high concentrations of CO_2 was advantage to the growth.

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